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ASSIGNMENT BOOKLET

SCN2261 Physics 20

Module 5 Assignment

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Physics 20

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Module 5

CIRCULAR MOTION

ASSIGNMENT BOOKLET



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Summary

	Total Possible Marks	Your Mark
Lesson 1 Assignment	32	
Lesson 2 Assignment	26	
Lesson 3 Assignment	20	
Lesson 4 Assignment	18	

Teacher's Comments

Physics 20
Module 5: Circular Motion
Assignment Booklet
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MODULE 5: LESSON 1 ASSIGNMENT

This Module 5: Lesson 1 Assignment is worth 32 marks. The value of each assignment and each question is stated in the left margin.

(32 marks) Lesson 1 Assignment: Understanding Circular Motion

TR 1. Use the Circular Motion: Horizontal simulation and Newton's laws to help answer the following questions.

- (2 marks) a. When the string is attached to the ball and the ball moves in a horizontal circle, does the string exert a force on the ball? If so, in which direction is the force always directed?
- (1 mark) b. While the string is attached to the ball and the ball moves in a horizontal circle, does the force change either or both the direction and speed of the ball? Explain.
- (1 mark) c. When the string is released, is there any force acting on the ball?
- (1 mark) d. According to Newton's first law, what type of motion should result when the string is released? Is this confirmed by your observations?
- (2 marks) e. When a ball is twirling at a uniform speed on the end of a string, the inward force is zero. Is this statement true or false? Explain your reasoning.
- (2 marks) f. An object can be accelerating while maintaining a uniform (constant) speed. Is this statement true or false? Explain your reasoning.
- (1 mark) **TR 2.** Suppose you were to reduce the radius of the arc through which you twirled a ball on a string by one-half. How would that affect the size of the inward force (tension) in the string?

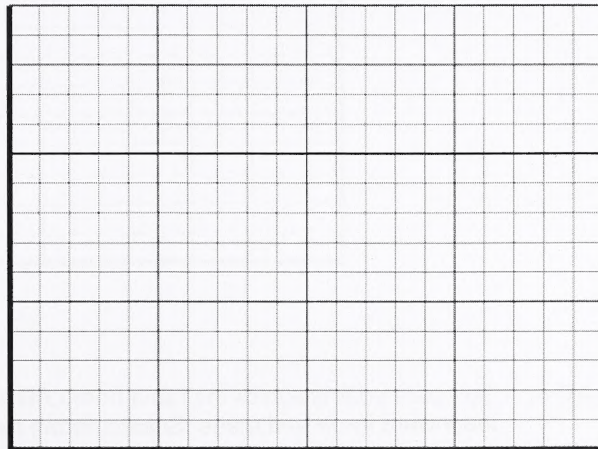
- (1 mark) **TR 3.** Suppose you were to increase the mass of the ball by five times. How would that affect the size of the inward force (tension) in the string?
- (3 marks) **TR 4.** Complete question 8 of "5.2 Check and Reflect" on page 268 of your textbook.

- (3 marks) **LAB 1.** Run the simulation, and adjust the radius to the values indicated in the following table. Record the inward force (tension).

Radius (m)	Inward Force (tension) (N)
0.5	
1.0	
2.0	
3.0	
4.0	
5.0	
6.0	
8.0	
10.0	

- (3 marks) **LAB 2.** Use the data from the table in LAB 1. Sketch the graph in the space provided below. (**Note:** You may enter the data into a spreadsheet and use the spreadsheet's graphing capabilities.)

Radius vs. Inward Force



- (1 mark) **LAB 3.** Compare your graph to the table in LAB 1, and state the relationship between the inward force and the radius. Substitute the term F_c for y and the term r for x .

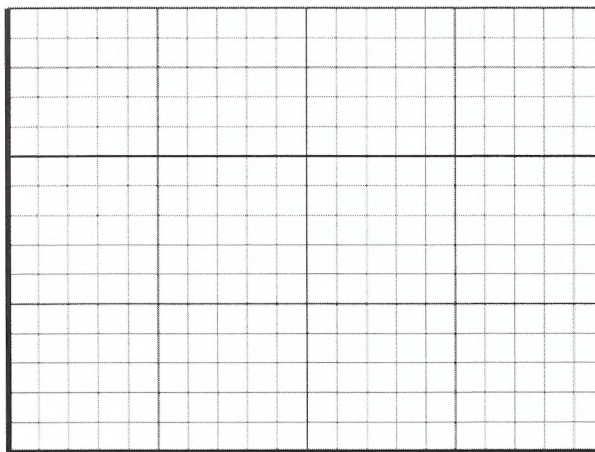
$$F_c \propto \underline{\hspace{2cm}}$$

- (3 marks) **LAB 4.** Run the simulation, and adjust the mass to the values indicated in the table below. Record the inward force (tension).

Mass (kg)	Inward Force (tension) (N)
1.0	
2.0	
3.0	
4.0	
5.0	

- (3 marks) **LAB 5.** Use the data from LAB 4. Sketch the graph in the space provided below. (**Note:** You may enter the data into a spreadsheet and use the spreadsheet's graphing capabilities.)

Mass vs. Inward Force



- (1 mark) **LAB 6.** Compare your graph to the table from LAB 4, and state the relationship between the inward force and mass. Substitute the term F_c for y and the term m for x .

$$F_c \propto \underline{\hspace{2cm}}$$

- (1 mark) **LAB 7.** Combine your answers from SC 7, LAB 3, and LAB 6 to produce a mathematical expression for the inward force as a function of mass, velocity, and radius.

$$F_c \propto \underline{\hspace{2cm}}$$

(1 mark) LAB 8. Show that this expression is dimensionally correct according to $F = ma$. In other words, the units for the equation in LAB 8 should be consistent with the fact that $1 \text{ N} = 1 \text{ kg}\cdot\text{m}/\text{s}^2$.

(2 marks) LAB 9. Derive an equation for the acceleration acting on an object moving along a circular path in a horizontal plane. (Equate Newton's second law, $F = ma$, to your expression for the inward force from LAB 8.) Find this equation in the Physics Data Booklet. You can find it on the Alberta Education website.

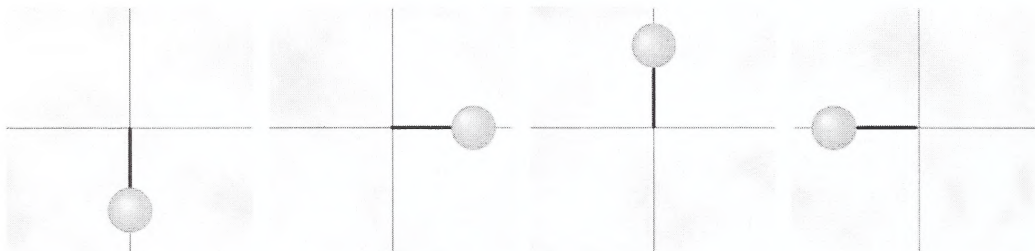
MODULE 5: LESSON 2 ASSIGNMENT

This Module 5: Lesson 2 Assignment is worth 26 marks. The value of each assignment and each question is stated in the left margin.

(26 marks) Lesson 2 Assignment: Newton's Laws Applied to Vertical Circular Motion

TR 1. Use the simulation, and observe the tension vector while the ball is rotating.

- (2 marks)** a. Label each of the following diagrams with the tension vector. (Remember to illustrate the relative magnitude of each vector.)



- (2 marks)** b. Identify which diagram has the greatest tension force, which diagram has the least tension force, and which two diagrams have the same magnitude of tension force.

- (1 mark)** c. The tension force is always directed towards the _____ of the circle.

- (1 mark)** d. The tension force is greatest at the _____ of the circle and least at the _____ of the circle.

TR 2. The inward force is the force needed to deflect the ball in a circular path. At the top of the arc, F_{inward} is the net force or sum of the weight and tension forces. Use the vector diagram of the ball at the top of the circle to answer the following questions.

- (1 mark)** a. Using the FBD for the ball at the top of the circle, write an equation for F_{inward} .

$$F_{\text{inward}} = \underline{\hspace{2cm}} + \underline{\hspace{2cm}}$$

- (1 mark)** b. What is the direction of the inward force at the top of the arc?

(1 mark)

- c. Rewrite the equation of F_{inward} , and include the direction of all of the forces. (Notice that at this infinitesimal instant, all of the forces are along the y -axis; so, you can use $+$ or $-$ to represent direction.)

$$\underline{\hspace{2cm}} = \underline{\hspace{2cm}} + \underline{\hspace{2cm}}$$

(1 mark)

- d. Manipulate this expression in terms of the tension force (T) in the rod.

$$T = \underline{\hspace{2cm}} + \underline{\hspace{2cm}}$$

(1 mark)

- e. An inward force can also be defined by the expression $F_{\text{inward}} = \frac{mv^2}{r}$. Remember that weight is defined as $W = mg$. Rewrite the equation from TR 2.d. by substituting these expressions.

TR 3. Set up the following conditions in the simulation. (The mass and radius settings can be adjusted by moving the sliders. Double-clicking the slider or clicking  allows you to enter an exact value for the variable.)

- mass of the ball = 3.0 kg
- initial velocity = 18.0 m/s
- radius of the arc = 1.0 m

Press "Play." Then press "Pause" when the ball is near the top of the arc. Click the ball and position it at the exact top of the arc so the angle shows 90.0° .

(1 mark)

- a. Record the speed at the top of the arc: $\underline{\hspace{2cm}}$ m/s

(3 marks)

- b. Calculate the expected tension in the rod at the top of the arc by doing the following:
- State the equation you derived in TR 2.e.
 - Calculate the tension acting at the top of the vertical loop using the mass, radius, and velocity at the top of the arc.
 - Verify your answer by checking the tension measurement on the simulation when the ball is positioned at the top of the arc.

tension measurement: _____ N

TR 4.

Set up the following conditions in the simulation. (The mass and radius settings can be adjusted by moving the sliders. Double-clicking the slider or clicking ) allows you to enter an exact value for the variable.)

- mass of the ball = 1.0 kg
- initial velocity = 7.0 m/s
- radius of the arc = 1.0 m

Press "Play." Then press "Pause" when the ball is near the top of the arc. Click the ball and position it at the exact top of the arc so the angle shows 90.0°.

(1 mark)

- a. Record the speed at the top of the arc: _____ m/s.

(6 marks)

- b. Calculate the expected tension in the rod at the top of the arc by doing the following:
- State the equation you derived in TR 2.e.
 - Calculate the tension acting at the top of the vertical loop using the mass, radius, and velocity at the top of the arc.
 - If the tension in the rod reaches zero at the top of the arc, the object is in a momentary state of free fall. Assuming the tension is zero, use the equation from TR 2.e. to derive an expression for the velocity at the top of the arc when an object undergoes free fall.
 - Explain what this equation will be used to calculate. Refer to a bucket of water in your explanation.

tension measurement: _____ N

(4 marks) **TR 5.** Complete question 3 in “Practice Problems” on page 264 of the textbook.

MODULE 5: LESSON 3 ASSIGNMENT

This Module 5: Lesson 3 Assignment is worth 20 marks. The value of each assignment and each question is stated in the left margin.

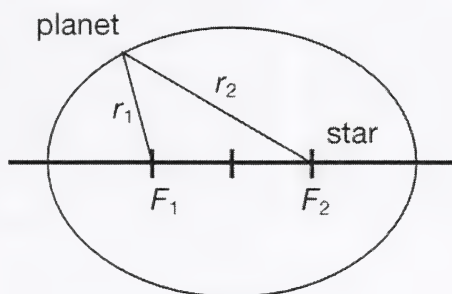
(20 marks) Lesson 3 Assignment: Kepler's Three Laws of Planetary Motion

(2 marks) TR 1. Use the simulation to investigate Kepler's first law.

- Click the "Reset" button (.
- Using the eccentricity slider, set the eccentricity (e) to 0.400.
- Using the semi-major axis slider (mean distance between the planet and the Sun), set (a) to 2.0 AU.
- Click the "Play" button (, and observe the planet (green) orbiting the Sun (yellow).

Draw the shape of the orbit and the location of the Sun relative to the orbit.

TR 2. Answer the following using the definitions above and the given values of r_1 and r_2 for the ellipse shown.



$$r_1 = 1.396 \times 10^{11} \text{ m}$$

$$r_2 = 2.432 \times 10^{11} \text{ m}$$

(1 mark) a. The longest mean orbital diameter (major axis) of the planet's orbit is

_____ m.

(1 mark) b. The mean orbital diameter expressed in astronomical units is

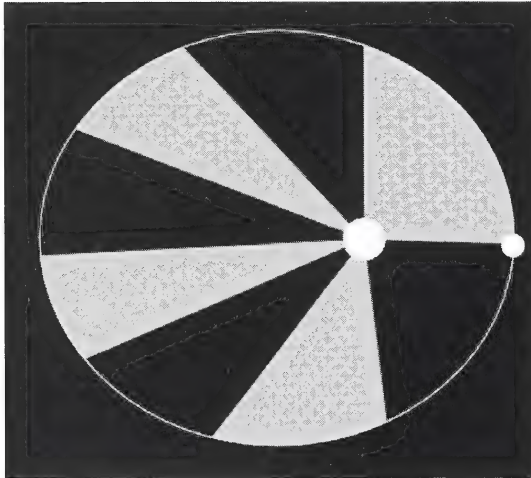
_____ AU.

TR 3. Use the simulation to investigate Kepler's second law.

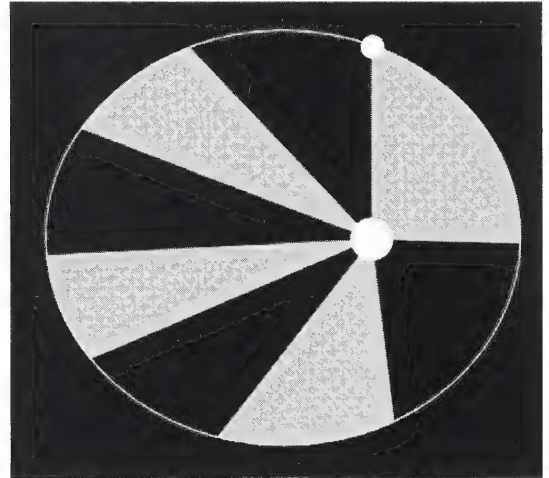
- Click the "Rewind" button ()
- Click the "Data" button ()^{1/2}. Move the ellipse to the right so you can see it all by clicking in the ellipse and dragging it to the right.
- Click the "Sweep" button ()^{1/2}. This will display sectors of equal area.
- Click the "Play" button ()^{1/2}. "Pause" the planet ()^{1/2}, and use the "Step forward" button ()^{1/2} to position the planet according to the following diagrams.

(1 mark)

a. Record the time display below each figure.



$t_1 =$ _____



$t_2 =$ _____

(1 mark)

b. Calculate the time interval for the planet to travel the sector ($t_2 - t_1$).

$$\Delta t = t_2 - t_1$$

$$= \text{_____}$$

(4 marks)

TR 4.

Using the same method as in TR 3, measure the times required for the planet to traverse at least three of these sectors of equal area. Compare the time values. What do you observe?

TR 5. Use the simulation to investigate Kepler's third law.

- Click the "Rewind" button ().
- Click the "Sweep" button (). This will hide the sectors of equal area.
- Click the "Play" button (.

(1 mark)

- a. Record the length of the semi-major axis (the mean or average distance between the planet and the Sun or mean *orbital radius*) from the slider at the bottom of the window. The conventional representation for orbital radius is r .

$r =$ _____ AU

(1 mark)

- b. Measure the period of the planet (the time to complete one revolution). You may want to click "Replay" () in order to set the time to zero before making any measurements.

trial 1: Period: _____ Year

(1 mark)

- c. Modify the eccentricity by adjusting the eccentricity slider. (**Note:** Do not adjust the semi-major axis.) Again, measure the period of the planet (time for one complete revolution).

trial 2: Period: _____ Year

(1 mark)

- d. Did changing the orbital eccentricity change the period of the orbit?

(2 marks)

TR 6.

Calculate Kepler's constant for the solar system using the recorded value for the semi-major axis length and the period from trial 1 or trial 2 in TR 5. (They should be the same.)

$K =$

- (2 marks) **TR 7.** Verify Kepler's constant by changing the length of the semi-major axis to 1.8 AU and recording the orbital period by clicking "Play" on the simulation and watching it for a complete orbit. Use the "Pause" and "Step" buttons near the end of the full orbit to get the time accurately. Calculate the constant of proportionality again. Circle the units of the proportionality constant.

$r =$ _____ AU

$T =$ _____ Year

$K =$ _____

Comment: In the units of AU and Year, the proportionality constant is numerically equal to 1. Notice that if T is in Years and r in AU, then the equation is as simple as $T^2 = r^3$.

- (2 marks) **TR 8.** The orbital radius (semi-major axis) of the orbit of Ceres, an asteroid circling the Sun between Mars and Jupiter, is 2.77 AU. Using Kepler's constant for the solar system, calculate the orbital period of Ceres in years.

MODULE 5: LESSON 4 ASSIGNMENT

This Module 5: Lesson 4 Assignment is worth 18 marks. The value of each assignment and each question is stated in the left margin.

(18 marks) Lesson 4 Assignment: Planetary and Satellite Motion

LAB 1. Complete the following steps:

- Reset the simulation.
- Select the “Trace” () , “Data” () and “Grid” () buttons.
- Zoom out by setting the “Scale” to $100 \text{ px} = 100\,000 \text{ km}$ so you can see Earth in its entirety.
- Use the “Display Vectors Selection Panel” button () to select the acceleration and weight (gravitational force) vectors, and then click off the “Display Vectors Selection Panel.”
- Play the motion. Observe the weight vector during the motion, as well as the weight value displayed in the data box. Press “Pause” at various points, if necessary, to look at the data.

(1 mark)

- a. Does either the weight vector or the weight value change?

(1 mark)

- b. Describe what happens to the direction of the weight vector as the satellite orbits Earth.

(1 mark)

- c. Describe what happens to the magnitude of the weight vector as the satellite orbits Earth. If it changes, how can this be explained using Newton’s equations for weight?

(2 marks) **LAB 2.** Is the satellite ever "weightless" in any orbit? Experiment with different orbits in different scale settings, and move the satellite as far away as possible. Explain your observations in terms of the equations that describe weight.

(3 marks) **LAB 3.** Complete the following steps:

- Reset the simulation.
- Use the "Display Vectors Selection Panel" button () to select the magenta velocity vector and the green force of gravity vector, and then click off the "Display Vectors Selection Panel."
- Display the data box in order to observe the satellite's weight. While the satellite is stationary, vary the satellite's initial velocity by dragging the tip of the velocity vector.

Do you see any changes in the force of gravity, the acceleration due to gravity acting on the satellite, or the value of the weight shown in the data box? Explain your observations in terms of Newton's universal law of gravitation. (Specifically, does the force of gravity depend on the velocities of the interacting objects?)

(2 marks) **LAB 4.** Find out if a projectile can become a satellite, given an appropriate initial velocity and position.

- Switch the "Scale" setting to 100 pix = 5000 km.
- Bring the satellite down to the surface by setting the x and y positions to 0 km, respectively; then drag the satellite up slightly.
- Turn on the velocity vector, and set it to 3 500 m/s in a horizontal direction ($\theta = 0^\circ$).
- Press "Play," and observe how far around the planet the satellite makes it before crashing into the surface.
- Try a variety of velocities until you are able to have the satellite orbit the planet successfully within the field of view.

Based on your observations, fill in the blanks with these terms: *large*, *small*, *parallel*, *perpendicular*.

A projectile will become a satellite in a nearly circular orbit when the magnitude of the velocity is _____ and it is directed _____ to Earth's surface.

(1 mark) **LAB 5.** Using a trial-and-error method, try to find the exact horizontal speed that a satellite would need to have at an altitude of 1000 km to make a circular orbit.

circular orbit speed = _____

(3 marks) **LAB 6.** Use the equation derived above to calculate the exact value of the initial speed that will produce a circular orbit of the satellite at an altitude of 1000 km above Earth. Verify your answer using the simulation, and compare it to your answer in LAB 5.

(4 marks) Discuss

In 1995, the first planet outside of our solar system was discovered and named “51 Pegasi b” after the star it orbits. Planets like this are called extrasolar because they are outside Earth’s solar system. Compared to the bright stars they orbit, extrasolar planets are very difficult to directly observe, given the astronomical distance they are from Earth. One of the most common and successful ways to find a planet is to observe the star it orbits.

Using the article titled “Then, Now, and Future: Extrasolar Planets” on page 283 of your textbook as a reference, propose an indirect method for finding extrasolar planets using the principles of circular motion and Newton’s universal law of gravitation. If such planets were discovered with this method, explain why it would be unlikely that life would exist on them.

Once you have completed all of the questions, submit your work to your teacher.

